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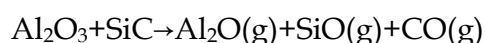


Liquid Phase Sintering of Silicon Carbide with AlN-Re₂O₃ Additives

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1. Introduction

Silicon carbide can be pressureless sintered by a solid stated process with the sintering aids of B and C to near full density at temperatures in excess of 2100°C (Prochazka, 1974). However, the lower fracture toughness (3 to 4 Mpa m^{1/2}) limit their use in many potential structural applications. It has been known that sintering of SiC can be achieved at relatively lower temperature (1850°C-2000°C) with the addition of oxides (Al₂O₃ and Y₂O₃) via liquid phase sintering (Omori & Takei, 1988; Nitin, 1994). The resulting material obtained with homogeneous and equiaxed fine-grained microstructure. Oxides like SiO₂ and Al₂O₃, which are normally considered as thermodynamically stable, are prone to react with SiC at temperature of about 2000°C, leading to formation of gaseous products such as CO, SiO and Al₂O.



In order to suppress these reactions, a powder bed is generally required (Tan et al, 1998). Alternatively, the additive system of AlN and rare earth oxides including Y₂O₃, is used where the decomposition of AlN into Al and N₂ can be efficiently controlled by using N₂ atmosphere, leading to lower weight lost (Chia et al, 1994; Ye et al, 20002). The AlN -Y₂O₃ phase diagram indicates that eutectic temperature in this system is about 1850°C (Kouhik, 2002). It might avoid forming a liquid with rather low melting temperature and a coarse surface of ceramic caused by vaporized gases from the reaction of SiO₂ and Al₂O₃-Y₂O₃. Also in this system the intermediate compositions can offer sufficient amount of liquid with melting temperature higher than 1700°C as sintering aid of LPS-SiC. Some studies have been carried out by using rare-earth oxide containing densification aids (Koushik et al, 2004; Koushik et al, 2005). Our previous study on melting behaviours of SiC and a series of Re₂O₃ (1 : 1 mol mixture) has shown that melting temperatures raise with increasing the atomic number of rare earth element (from La to Er and Y) (Wu et al, 2008). The aim of this work was to study the sintering behavior of liquid phase sintered SiC with AlN and Re₂O₃ (La₂O₃, Nd₂O₃, Y₂O₃) additive system and their mechanical property in both pressureless sintering and hot press sintering.

2. Material and Method

2.1 Materials

The submicron α -SiC powder was manufactured by Beifang University of Nationalities. SiC content >97% (mass fraction, the same below), free C<1%, SiO₂<1.2%; median particle size of the powder: D₅₀ = 0.7 μ m. AlN powder (D₅₀ < 0.8 μ m, purity>98%) were provided by Beijing Iron Research Institute, Y₂O₃, La₂O₃ and Nd₂O₃ (purity>99.9% D₅₀ = 2-5 μ m) was provided by Baotou Rare Earth Research Institute. The particle size distribution of the powders was measured by Laser Sizer (model Microtrac X-100, Honeywell, USA). The chemical analysis of the SiC powder was carried out according to Abrasive Grains -chemical analysis of silicon carbide(National Standard of China GB/T 3045-2003) .

2.2 Experimental Methods

2.2.1 Preparation of the powder mixtures

SiC powder and additives were mixed in an attrition mill for about 1 hr in alcohol using Si₃N₄ balls as medium. The compositions of various powder mixtures prepared and the nomenclature used to describe the samples are specified in Table 1. All of the powder mixtures have content of 85% SiC and 15% additives(mass fraction) except "Slay -1". The milled slurry was separated from the milling media and possible wear debris by screening through 320 mesh screen. The slurry was dried in a stirring evaporator and completely dried in a drying oven at 80°C. The dried powder mixture was sieved through 100 mesh.

sample code	AlN /mol%	Y ₂ O ₃ /mol%	Nd ₂ O ₃ /mol%	La ₂ O ₃ /mol%	Theoretical Density ρ /g·cm ⁻³
Sly-1	40	60	0	0	3.40
Sly-2	60	40	0	0	3.38
Sly-3	80	20	0	0	3.34
Sln	60	0	40	0	3.50
Slny	60	20	20	0	3.44
Sla	60	0	0	40	3.47
Slay	60	20	0	20	3.43
Slay-1*	66	17		17	3.45

*Sample " Slay - 1 "has 80% SiC and 20% sintering additives (mass fraction)

Table 1. Compositions and Theoretical Density of powder mixtures

2.2.2 Pressureless Sintering

The mixed powder was axial pressed under pressure of 100Mpa and then cold isostatic pressed under 250 MPa. The rectangular shaped green samples of approximately 10×50×50 mm were sintered in a graphite furnace (made by Robert furnace Co. China). The samples were put into a graphite crucible using BN powder as separator. A high purity N₂ gas atmosphere was used during sintering. The gas pressure was maintained at 0.02 Mpa during sintering. The samples were sintered at 1800, 1850, 1900, 1950, 2000°C and 2050°C for

1 hr separately. Heating rates of 20°C/min from ambient temperature to 1600°C and 10°C/min from 1600°C to final sintering temperature were used.

2.2.3 Hot press sintering

The powder mixtures were put in a 40 mm ×40 mm graphite mould (lined with BN powder as separator), hot press sintered under an axial pressure of 30 MPa in N₂ protected atmosphere with a sintering temperature of 1850 °C, held for 0.5 h (the furnace made by Shanghai Chenrong Co., China).

2.3 Characterization

The weight loss and linear shrinkage of both green body and sintered specimen of all samples were measured. Bulk density were measured by Archimede's principle by a water displacement method. The hardness was determined by using a load of 98 N in a micro-hardness test fitted with a Vickers square indenter (Wolpert U.S.A). The fracture toughness was calculated by the length of the cracks originating from the edges.: $K_{IC}=0.016 (E/Hv)^{0.5} \times (p/c-1.5)$ where K_{IC} is the fracture toughness of the material, Hv is the Vickers hardness, E is the Young's modulus (for LPS-SiC a value of 400 was assumed) c is the crack length(μm) and a is indentation diagonal (Anstis et al, 1981). The specimens were cut into rectangular beams with dimensions of 3×4×36 mm to test three point bending strength. The tensile edges were bevelled to remove stress concentrations and edge flaws caused by sectioning. Observation of the microstructure has been performed by SEM (SSX-550 Shimadzu Japan) on fracture surfaces and also on finished surface polished by 1 μm diamond paste. The phase composition of samples was determined by X-ray diffraction using Cu-Kα radiation (XRD-6000 Shimadzu Japan) , a step width of 0.2 with an exposure time of 2 degree/min per position.

3. Results and discussion

3.1 Sinterability of SiC-AlN-Y₂O₃ system

Similar to other works (Rixecker et al, 2000; Magnani & Beaulardi 2005), the sintering temperature for completed densification is a function of the additive composition and the best densification behavior does not coincide with the eutectic composition in the AlN-Y₂O₃ system(See Fig 1) (Kouhik, 2002), which is about 40 mol% AlN as shown in Fig 2. Sample Sly-2 with 60 mol%AlN reached full density at much lower temperature compared with the other two samples. Further more the temprature range of dentification is much wider than others also. It can be seen obviously that the sample with less AlN content as Sly-1(with 40%AlN) need higher sintering temperature and has very limited adaptive temperature range. Sample Sly-3(with 80%AlN) need even higher sintering temperature, its adaptive sintering temperature range is also very limited. It is well known that an important requirement of liquid phase sintering is that there must be good wetting of the solid phase (SiC) by the liquid phase (additive) and there must be a small contact angle θ between the solid SiC and the liquid drops formed by the additive. R.M.Balestra's work showed that at this additive system with 60%mol% AlN had good wettability ($\theta_{min} \cong 6^\circ$)(Balestra, et al, 2006).The viscosity of silicate melts increases with their nitrogen content, in analogy to the glass transition temperatures of oxynitride glasses.

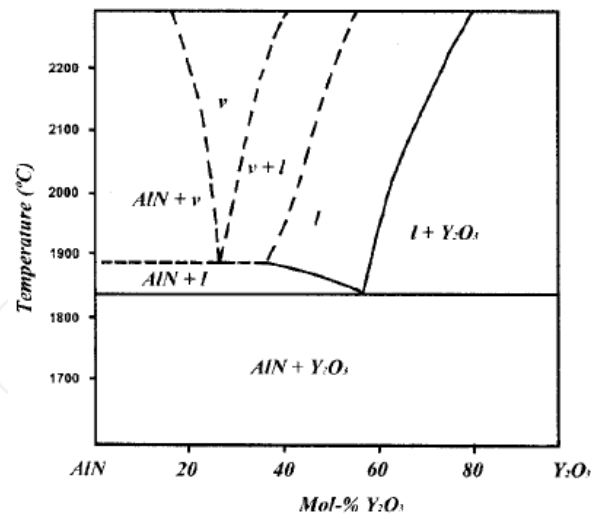


Fig. 1. Phase diagram of the Y₂O₃/AlN system(Kouhik, 2002)

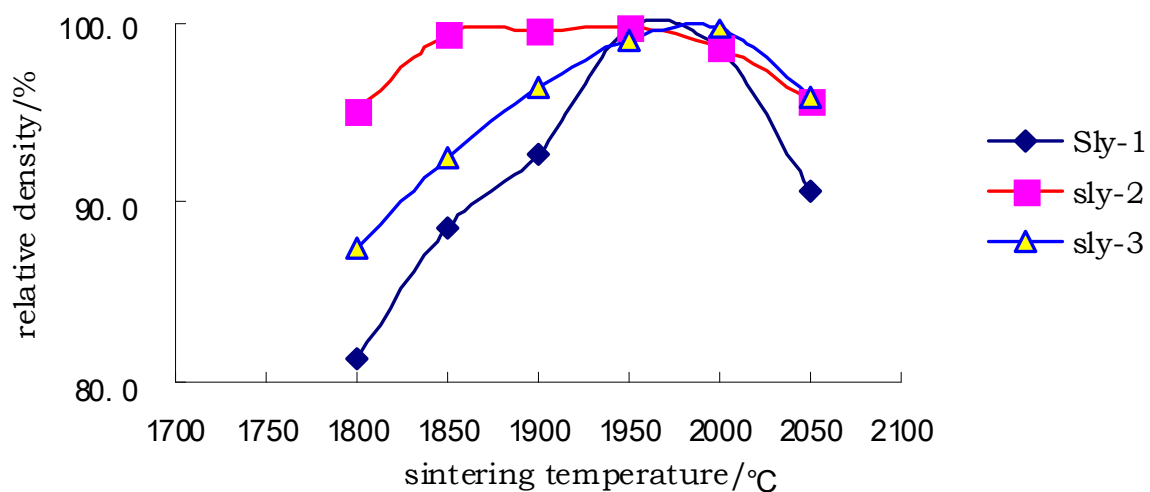


Fig. 2. Sinterable behavior as a function of nitrogen content in the additive

The weight loss of all full density specimens kept about 2%, as shown in Fig 3. When the sintering temperature was raised higher than 2000°C, the weight loss of all specimens increased rapidly up to more than 5%, and the diametric linear shrinkage was less than those in full density temperature. Hence at that temperature, additive decomposition made the density of specimens decrease. It can be seen from Fig. 3 that Sly-1 has less shrinkage than others in the whole temperature range, and less weight loss at lower temperature. Among all samples, Sly-3 has the most even curve both in shrinkage and weight loss. It will bring more convenient sintering process design for densification of SiC. Experimental results showed that SiC-AlN-Y₂O₃ could be fully densified in wide temperature range (1850°C-2000°C), and keep low weight loss around 2% in this range. The surface of specimens remains smooth, indicating that sintering could be done without powder bed.

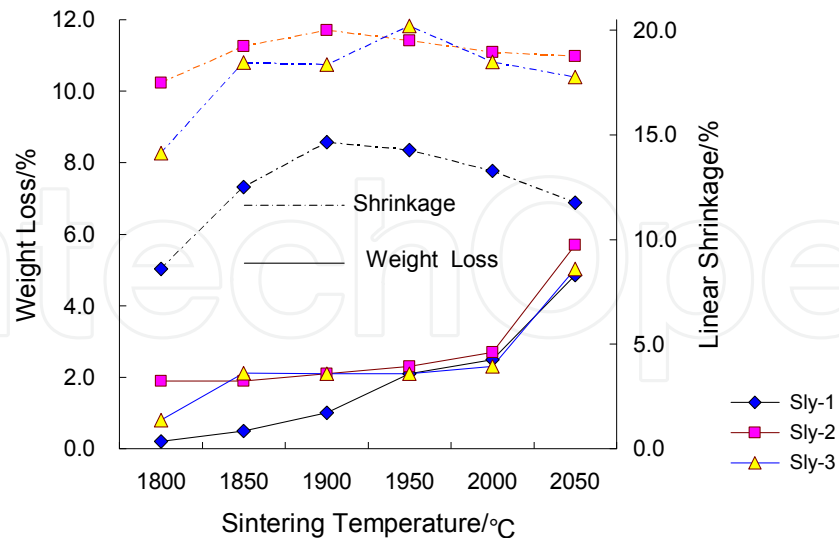


Fig. 3. Weight loss and linear shrinkage of samples VS sintering temperature

It can be seen in the phase diagram of the Y_2O_3/AlN system shown in Fig. 1 that there is a liquid region with sharp lines between the gas(v)/liquid(l) phase region and liquid / Y_2O_3 region. Its eutectic point is near 1830 °C(Kouhik, 2002) . The actual sintering temperature is close to the eutectic temperature in order to prevent unfavorable influence of volatilization. The material with the liquid region composition showed less mass loss during high temperature sintering. Experimental results show that SiC-AlN- Y_2O_3 can be fully densified over a wide temperature range (1850°C-2000°C), and keep low weight loss around 2%. The surface of specimens remains smoothly, indicating that sintering could be done without powder bed.

3.2 Sinterability of SiC-AlN- R_2O_3 (R=Nd, La) systems

The best sintered density and corresponding weight loss data of specimens of all test using AlN- Re_2O_3 additive system by using pressureless sintering are shown in Table 2. These test results indicated that the specimens wouldn't been fully densified by using AlN- Nd_2O_3 or AlN- La_2O_3 additive system, all these systems showed much higher weight loss than those results reported in gas pressure sintering (Izhevskiy et al, 2003) which indicated much decomposition reaction occurred without N_2 gas protection.

sample code	Sintering temperature/°C	Weight loss /%	RD ρ/%
Sln	1900	5.9	96.5
Slny	1950	3.1	99.2
Sla	1900	6.9	92.4
Slay	1950	5.1	98.1
Slay-1	1930		97.0
Slay-1 (H P)*	1850		99.3

*Slay-1(HP) was sintered by hot press

Table 2. sintering density and weight loss of AlN- R_2O_3 systems

Interestingly, AlN-Re₂O₃-Y₂O₃ additive system showed much better sintering behaviours than AlN-Re₂O₃ system. Although more weight loss occurred than in the AlN-Y₂O₃ system did, and higher sintering temperature was needed for densification.

3.3 Mechanical properties

Mechanical properties of all densified specimens are summarized in Table 3. For AlN-Y₂O₃ system specimens, the hardness (Hv) increased with increasing AlN content. AlN-Nd₂O₃-Y₂O₃ additive specimen show higher hardness than that of all other specimens, which has same hardness as SSSiC (21-25 GPa) (Wu A., et al, 2001). All specimens have bending strength in range of 350-500 MPa. All specimens have relative higher fracture toughness compared to SSSiC which is in range of 3-5 MPa m^{1/2}. The SEM picture of crack and the fracture surface are shown in Fig 4. The indicated fracture mode was intergranular fracture. Grain refinement and inter-crystal deflection are the main reasons for the toughness increasing.

sample code	Hardness /GPa	Bending strength/Mpa	Fracture toughness /MPa m ^{1/2}
Sly-1	18.7±0.7	410±4.8	6.8±0.4
Sly-2	19.4±0.8	435±42	8.0±0.7
Sly-3	20.8±0.2	481±57	6.1±0.2
Sly	22.2±0.2	--	6.9±0.3
Slay	18.9±1.1	367±13	6.5±0.3
Slay-1	20.5±1.2	434±52	4.8±1.0
Slay-1(HP)	19.0±1.0	828±55	8.6±1.9

Table 3. mechanical properties of best densified specimens

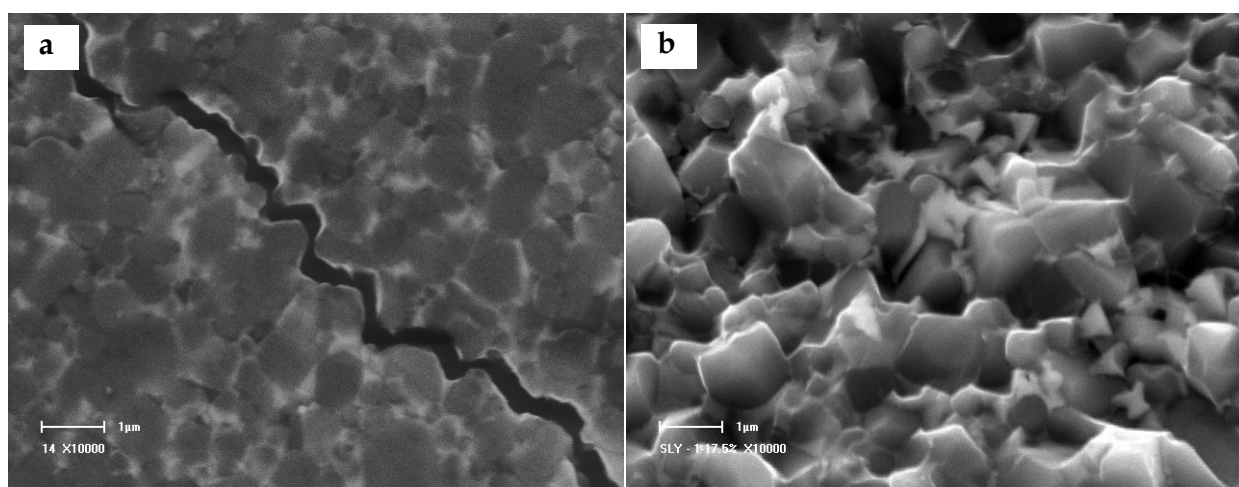


Fig. 4. SEM picture of crack deflection and break surface of sly-2 sample (a. crack deflection, b. fracture surface)

3.4 Microstructure and phase composition

3.4.1 SiC-AlN-Y₂O₃ system

Typical microstructure of AlN-Y₂O₃ system are shown in Fig 5, similar to the microstructure described in previous report (Rixecker G., et al, 2001, Koushik B., et al, 2005, Wu L., et al, 2008, L.S.Sigl, 2003). The SiC grains are predominantly equiaxed with a mean grain size of 1-2 μm. Relatively little grain growth occurred during densification, indicating that the atomic transport through the melt is sluggish. The core-rim structure is found more clearly in higher AlN content samples.

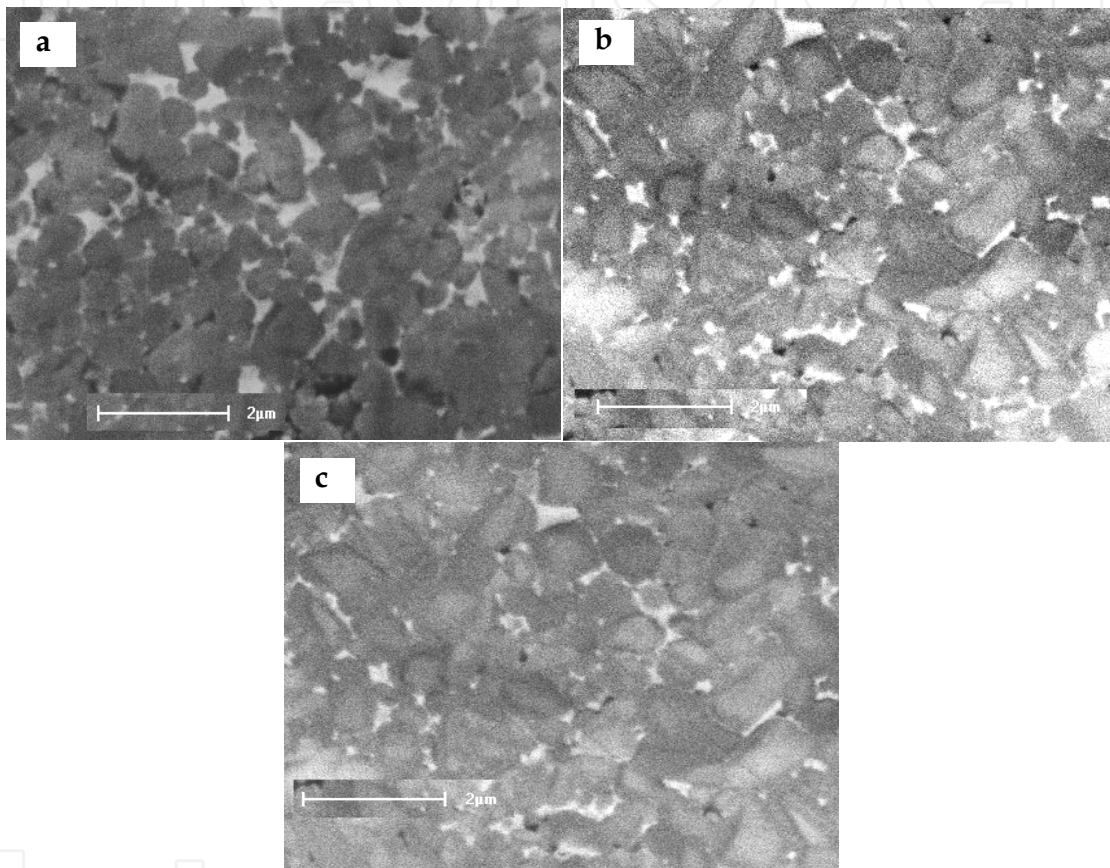


Fig. 5. Microstructure of LPS-SiC with AlN-Y₂O₃ additive
a) sly-1, b) sly-2, c) sly-3

The XRD pattern of the sample is shown in Fig 6. The major phase is 6H - SiC, the minor phases are AlN, Y₂O₃ and Y_{0.54}Si_{9.57}Al_{2.43}O_{0.81}N_{15.19} (α -Sialon). The work of Haihui Ye described that for sample sintered in 1 MPa N₂ atmosphere the AlN, Y₁₀Al₂Si₃O₁₈N₄, and Y₂Si₃N₄O₃ phase (melilite) were identified; but in Ar, Y₂O₃ and Y₁₀Al₂Si₃O₁₈N₄ phase were identified (YE. et al, 2002). Formation of minor Y₂Si₃N₄O₃ (melilite) means that a little SiC has been reduced/nitrided to be Si₃N₄ during firing in 1 MPa N₂ atmosphere. In this experiment the nitridation of partial SiC to Si₃N₄ also happened in N₂, 0.02 atm. leading to the formation of Y_{0.54}Si_{9.57}Al_{2.43}O_{0.81}N_{15.19} (α -Sialon), which was from the reaction of the compositions on the one dimension α -Sialon line of Si₃N₄-Y₂O₃:9AlN with the formula of Y_xSi_{12-(m+n)}Al_(m+n)O_nN_{16-n}, x=0.33-0.67 (Sigl, 2003). It has been shown that the core-shell

structure which can be seen clearly in Fig 5 formed mainly by solution-precipitation of oxynitride or α -Sialon during matter transport.. The subsolidus phase diagram of SiC-AlN-Y₂O₃ system in N₂ is shown in Fig 7.

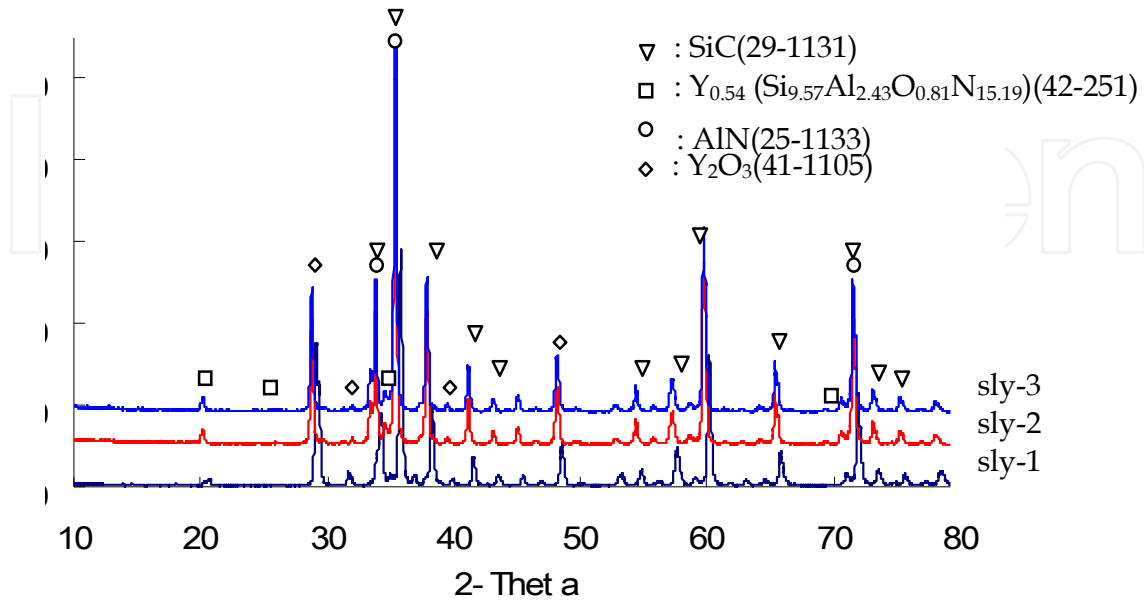


Fig. 6. XRD analysis of sintered sample with AlN-Y₂O₃ additive

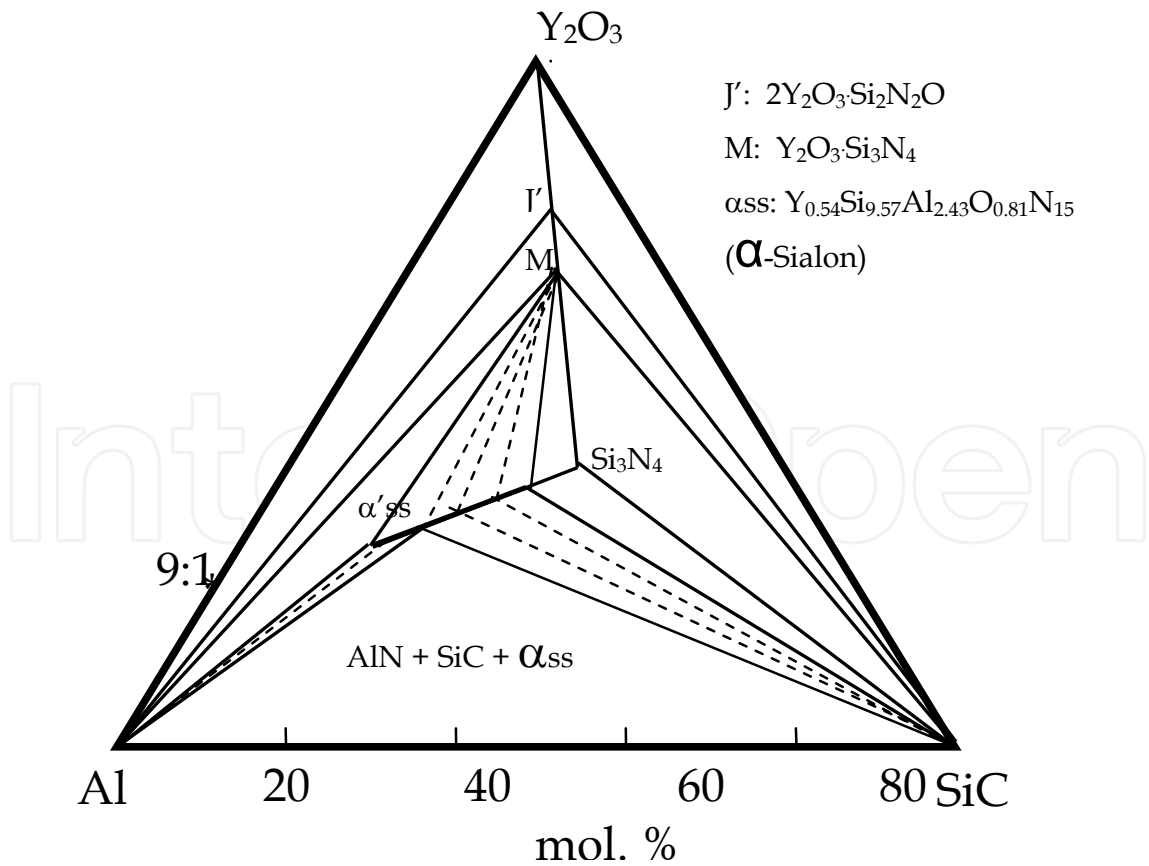


Fig. 7. Subsolidus phase diagram of SiC-AlN-Y₂O₃ system in N₂

* See Huang 1983

3.4.2 SiC-AlN-R₂O₃ (R=Nd, La) systems

For the AlN-Re₂O₃-Y₂O₃ additive system, the microstructure of LPS- SiC is similar to the AlN-Y₂O₃ system, but core-rim structure are hardly found in SEM(Fig 8 a),b),c)). Only in the hot-pressed samples (Fig 8 d)), “core-shell” could be observed obviously. Although the SEM images shown in Fig 8 c) and d) came from the samples with exactly the same composition. The different sintering process bring unlike microstructure of the ceramics. Certainly hot press sintering gains better results. It can be further explained by their mechanical properties.

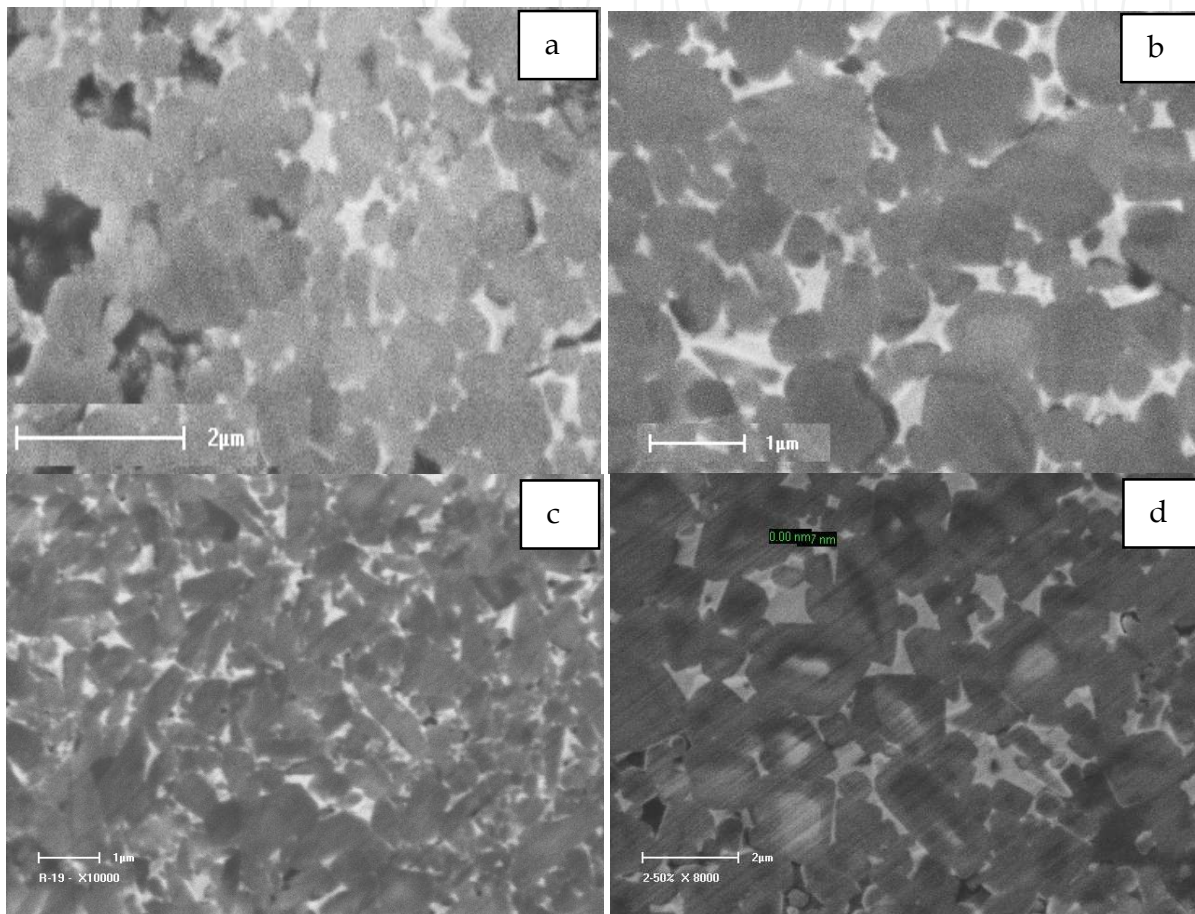


Fig. 8. Microstructure of LPS-SiC with AlN-Re₂O₃ additive
a) slny, b) slay, c) Slay-1, d) Slay-1(HP)

The XRD pattern of the sample with AlN-Nd₂O₃-Y₂O₃ additive is shown in Fig 9, two nitrogen-rich phases of Y_{0.54}Si_{9.57}Al_{2.43}O_{0.81}N_{15.19} (α-Sialon) and Nd₄Si₂O₇N₂ (NdAM') were found.

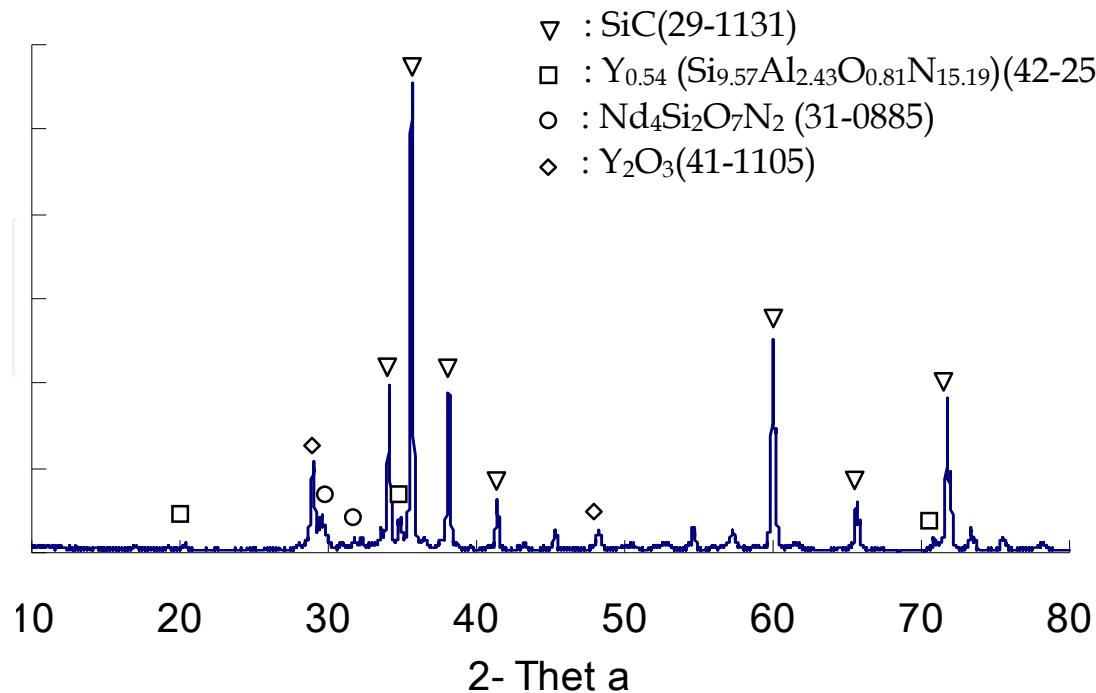


Fig. 9. XRD analysis of sintered sample with AlN-Nd₂O₃-Y₂O₃ additive

4. Conclusion

1. Fully dense SiC ceramics were obtained by liquid phase sintering with AlN-Y₂O₃ and AlN-R₂O₃-Y₂O₃ additives. Materials with 60mol% AlN in AlN-Y₂O₃ additives show that SiC can be sintered over a wide temperature range (1850°C-2000°C), and keeps low weight loss around 2%. The surface of specimens remains smooth, indicating that sintering could be done without powder bed. The specimens made using the AlN-R₂O₃-Y₂O₃ additives systems show higher weight loss, around 5%.
2. The materials obtained have fine-grained and homogeneous microstructure. The core-rim structure can be found in high AlN content specimen. All specimens have higher fracture toughness in the range of 6-8 MPa m^{1/2}. Grain refinement and inter-crystal deflection are the main reasons for toughness increasing. The specimens for AlN-Nd₂O₃-Y₂O₃ additive system showed higher hardness.
3. XRD analysis identified that nitrogen-rich phases of Y_{0.54}Si_{9.57}Al_{2.43}O_{0.81}N_{15.19} (α -Sialon) in AlN-Y₂O₃ additive system and Nd₂Si₄O₇N₂ (NdAM') in AlN-Nd₂O₃-Y₂O₃ additive system formed in the present study, indicating partial SiC was reduced/nitrided to Si₃N₄ or Si₂N₂O.

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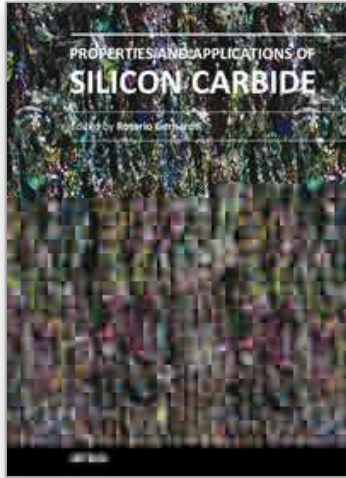
(50962001). The authors are grateful to Mr. Jiang and Mr. Han for their assistance with experiments.

5. References

- Huiwen Xu, et al. Microstructural evolution in Liquid-Phase-Sintered SiC : Part 1, Effect of starting powder. *J. Am. Ceram. Soc.*, 2001, 84[7]1578-1584. ISSN :1551-2996
- G.R.Anstis, P.Chantikul, B.R.Lawn and D.B.Marshall. A critical evaluation of indentation techniques for measuring fracture toughness I Direct crack measurements. *J. Am. Ceram. Soc.*, 1981, 64[9]533-543. ISSN :1551-2996
- K.Y.Chia, W.D.G.Boecker and R.S.Storm.U.S.Pat., 5, 298, 470(1994)
- Koushik Biswas. Liquid phase sintering of SiC ceramics with rare earth sesquioxides [D]. Stuttgart: University of Stuttgart, 2002.
- Koushik Biswas Rixecker.G, Aldinger F.. Effect of rare-earth cation additions on the high temperature oxidation behaviour of LPS-SiC. *Materials Science and Engineering A* 2004, 374 56–63. ISSN :0921-5093
- Koushik Biswas, Georg Rixecker, Fritz Aldinger. Gas pressure sintering of SiC sintered with rare-earth-(III)-oxides and their mechanical properties. *Ceramics International* 2005, 31 703–711. ISSN : 0272-8842
- L.S.Sigl. Thermal conductivity of liquid phase sintered silicon carbide. *J. Euro. Ceramic Soc.*, 2003, 23, 1115-112 ISSN : 0955-2219
- M. Balog, P. Šajgal'ik, M. Hnatko, Z. Len'čes, F. Monteverde, J. Ke'ckes, J.-L. Huangd Nanoversus macro-hardness of liquid phase sintered SiC. *J. Euro. Ceramic Soc.*, 2005, 25, 529–534.. ISSN : 0955-2219
- Magnani, G. and Beaulardi, L.. Properties of liquid phase pressureless sintered SiC-based materials 83 obtained without powder bed. *J.Aus.Ceram.Soc.*, 2005, 41(1), 31-36. ISSN :0004-881X
- Nitin P. Padture. In situ-toughened silicon carbide. *J.Am.Ceram.Soc.*, 1994, 77[2]519-23 ISSN :1551-2996
- Omori M, Takei H. Preparation of pressureless sintering of SiC-Y₂O₃-Al₂O₃. *J Mater Sci*, 1988, 23(10): 3 744–3 747. ISSN :
- Prochazka S. Sintering of silicon carbide// *Proceedings of the Conference on Ceramics for High Performance Applications* (Hyannis, MA). Hyannis: Brook Hill Publishing Co, 1975: 7–13.
- Rixecker G, Biswas.K, Wiedmann I and Aldinger.F.. Liquid-phase sintered SiC ceramic with oxynitride additives. *J.Ceramic processing research* 2000, 1:1 12-19. ISSN :1229-9162
- Rixecker G, Wiedmann I, Rosinus A, et al. High-temperature effects in the fracture mechanical behaviour of silicon carbide liquid-phase sintered with AlN-Y₂O₃ additives. *J.Euro. Ceram Soc.*, 2001, 21: 1 013–1 019. ISSN :0955-2219
- R.M. Balestra, S. Ribeiro, S.P. Taguchi, F.V. Motta, C. Bormio-Nunes Wetting behaviour of Y₂O₃/AlN additive on SiC ceramics. *J. Euro. Ceram. Soc.*, 2006, 26(16) 3881–3886 ISSN :0955-2219
- TAN Shouhong, CHEN Zhongming, JIANG Dongliang. Liquid phase sintering SiC Ceramics. *J. China Ceram Soc.*, (in Chinese), 1998, 26(2): 191–197. ISSN :0454-5648

- V.A.Izhevskiy, L.A.Genova, A.H.ABressiani, J.C.Bressiani Liquid phase sintered SiC processing and Transformation controlled microstructure tailoring. Material research, 2000, 3[4]131-138. ISSN :1516-1439
- Wu Laner, Chen Yuhong, Jiang Yong, Huang Zhenkun. Liquid sintering of SiC with AlN-Re₂O₃ Additives. J.of the Chinese ceramic society 2008, 36, [5] 593-596 .ISSN : 0454-5648
- Wu Anhua, Cao Wenbin, Li Jiangtao, Ge Changchun. Solid State Sintered SiC Ceramics. J. of Materials Engineering(China), 2001, 4, 3-5. ISSN :1001-4381
- Ye Haihui, Rixecker.G, Siglinde. H, et al. Compositional identification of the intergranular phase in liquid phase sintered SiC. J Euro Ceramic Soc., 2002, 22: 2 379-2 387. ISSN :0955-2219
- Z. K. Huang, P. Greil, G. Petzow, Formation of α - Si₃N₄ solid solution in the system Si₃N₄-AlN-Y₂O₃. J. Am. Ceram. Soc., 1983, 66, C96-C97. ISSN :1551-2996

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Properties and Applications of Silicon Carbide

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In this book, we explore an eclectic mix of articles that highlight some new potential applications of SiC and different ways to achieve specific properties. Some articles describe well-established processing methods, while others highlight phase equilibria or machining methods. A resurgence of interest in the structural arena is evident, while new ways to utilize the interesting electromagnetic properties of SiC continue to increase.

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